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(NASA-CR-175853) INFLUENCE OF COHERENT
MESOSCALE STRUCTURES ON SATELLITE-BASED
DOPPLER LIDAR WIND MEASUREMENTS Progress
Report for period ending May 1985 (Simpson
Weather Associates) 14 p BC A02/BF A01

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INFLUENCE OF COHERENT MESOSCALE STRUCTURES
ON SATELLITE-BASED DOPPLER LIDAR
WIND MEASUREMENTS

NASA Contract #: NAS8-35597

Monthly Progress Report

for

May 1985

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A. During the month of May we have focused primarily upon developing a rational basis for the choice of shot pairs and their appropriate weighting in the MPA. Specifically we have looked at:

- * range dependent weighting functions.

In addition we have

- * examined the single shot SNR as a function of scan angle,
- * simulated a space shuttle lidar experiment using a fixed beam and rotating shuttle,
- * participated in the NASA/MSFC's Atmospheric Review Program (6-10 May), and
- * assembled data for two case studies (SESAME 79 and AVEVAS II to be used with the NASA/MSFC's McIDAS system during the second week in June.

B. No contract scheduling problems are anticipated.

C. During the month of June most of our attention will be on the case studies. Two specific cases have been selected:

1) 20 May 1979

St. Louis University has produced an internally consistent set of gridded winds for several time periods during this mesoscale storm. The satellite imagery is already on the MSFC system. A program to overlay the gridded data has been written. The primary task is to select specific images that represent various degrees of obscuration of the mesoscale wind circulations and then perform lidar simulations on the exposed wind field in order to demonstrate the sensitivity of the lidar sampling to cloud distributions.

2) 6-7 March 1982

Mike Kalb (NASA/MSFC) has produced a set of gridded winds using the MASS model for a severe storms situation during the AVEVAS II experiment. Once again, the satellite imagery is on the McIDAS system. The remaining task is to overlay the model winds on the VIS imagery and to perform the lidar wind simulations.

D.	i) Total cumulative costs as of 1 June 1985	\$74631.24
	ii) Total costs for reporting month of May 1985	6988.56
	iii) Estimated costs to complete contract	97671.00
	iv) % of physical completion (on 1st year of contract)	77%

Expansion on Item A

* Range dependence of weighting functions

Although we have not yet found the optimum way to adjust the weighting function for range, we have been able to demonstrate the range dependence in Figures 1-3. Figure 1 is for an area close to the satellite ground track. The error index begins around 0.2 and only when 80 or more shot pairs are used does the error begin to rise. This is caused by the individual shot errors increasing faster than weighting functions can adjust for the increasing shot spacing. In Figures 2 and 3 (for mid and far range cases) the behavior of the Error Index with increasing numbers of shot pairs is different. In fact these latter two cases imply that the best wind estimate is obtained with 15 to 20 pairs. However, if another set of weighting functions were used, this number would change. Hopefully by next report period we will have found the best method to define optimum weighting functions.

* Single shot signal to noise ratio

As our efforts to identify sources of error in the lidar wind estimate shift to the individual pulse scale we are interested in the sensitivity of the SNR equation to the expected ranges of variation in the backscatter coefficient β , the atmospheric absorption coefficient μ , pulse length, scan angle, and orbit altitude. We have coded the SNR as described in a NASA memo distributed by J. W. Bilbro (EB-23) and dated 6 March 1985.

Accepting the 5 db threshold for a useful SNR for a single lidar pulse, we find in Figures 4-7 that for a 10 joule system and a backscatter β of 10^{-8} , a wave length of 9.11 certainly allows us to scan at our desired $55^\circ - 60^\circ$ from nadir over the range of standard atmospheres. At $10.6 \mu\text{m}$ we are limited to $40-45^\circ$ because of the tropical absorptions. When you consider that 10^{-8} for β is optimistic for the mid-troposphere and that 10^{-9} or 10^{-10} may be more realistic, then even for $9.11 \mu\text{m}$ angles greater than $30-40^\circ$ may not be practical. These computations serve to emphasize the need to have reliable measurements of β for a variety of atmosphere regimes. The impact on early design and engineering requirements is obvious. For the immediate future we will assume a β of 10^{-9} and a μ of .08 (for $9.11 \mu\text{m}$) as minima.

* Simulated Space Shuttle Lidar Experiment

Realizing the possibility of a space shuttle mission for a Doppler lidar, we performed a very preliminary simulation of a likely scan pattern and the wind field calculations that could be expected. Figure 8 is the scan pattern for an orbit altitude of 180 km, an orbit speed of 7.0 km/sec, a scan rate of $2^\circ/\text{sec}$ and a PRF of .2 (chosen as a minimum). Figures 9 and 10 illustrate the resulting wind estimates for correlated ($du/dx = dv/dy = 4 \times 10^{-6} \text{ s}^{-1}$) and uncorrelated wind fields.

Figure Captions

Figure 1. Error Index as a function of the number of ranked pairs used. The weighting functions are the original:

$$W_d = \frac{D}{D + 9X}$$

$$W_a = \cos (90 - B)$$

where D = diagonal of target area

X = distance between shots in a given pair

B = angle between shots in a given pair

The correlated wind field is $\frac{du}{dx} = \frac{dv}{dy} = 4 \times 10^{-6} \text{ s}^{-1}$

Figure 2. Same as Figure 1 except for mid range area 7.

Figure 3. Same as Figure 1 except for far range area 12.

Figure 4. SNR (db) in a tropical clear troposphere as a function of scan angle from the nadir for the following parameters:

System efficiency = 10%
Pulse energy = 10 Joules
Backscatter coefficient = $1 \times 10^{-8} \text{ m}^{-1} \text{ sr}^{-1}$
Pulse duration = $6 \times 10^{-6} \text{ s}$
Aperture diameter = 1 m
Truncation factor = .46
Atmospheric absorption coefficient. (Variable)
Range = 600 km
Photo energy = $1.8752 \times 10^{-20} \text{ Joules}$

Figure 5. Same as Figure 4 except that an absorption coefficient for a midlatitude winter clear troposphere was used.

Figure 6. Same as Figure 4 except that a wavelength of $9.11 \mu\text{m}$ was used.

Figure 7. Same as Figure 5 except that a wavelength of $9.11 \mu\text{m}$ was used.

Figure 8. Shot pattern on the ground for a shuttle based lidar with fixed optics. Scanning is achieved by rotating the shuttle at $2^\circ/\text{sec}$.

Figure 9. Wind estimates obtained with the MPA for the scan pattern shown in Figure 8. A correlated wind field is used with

$$\frac{du}{dx} = \frac{dv}{dy} = 4 \times 10^{-6} \text{ s}^{-1}$$

Figure 10. Same as Figure 9 except an uncorrelated wind field was used.

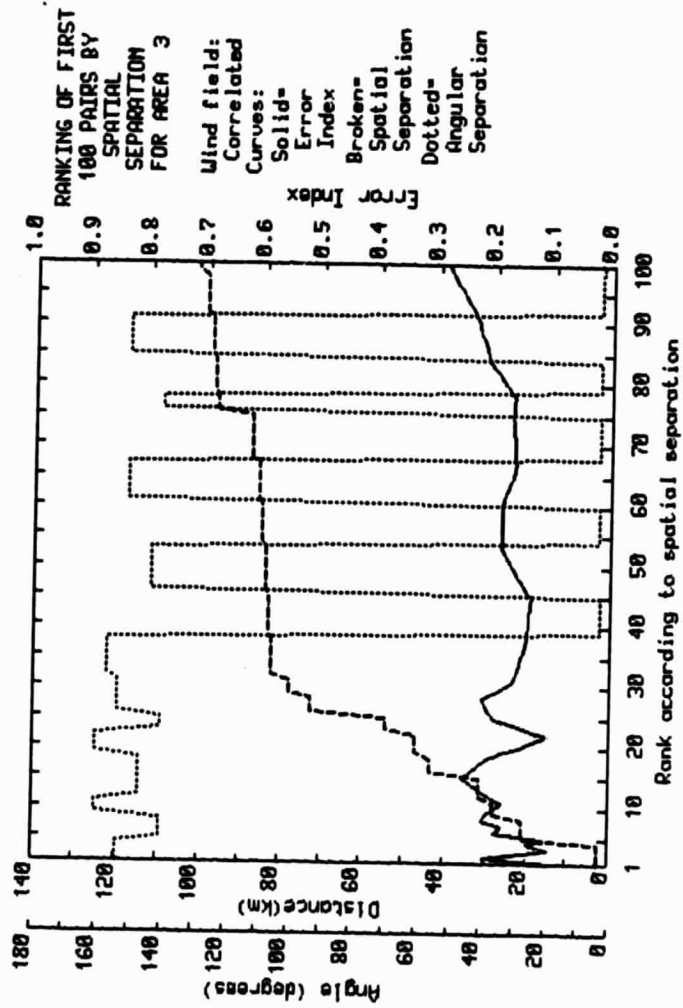


FIGURE 1

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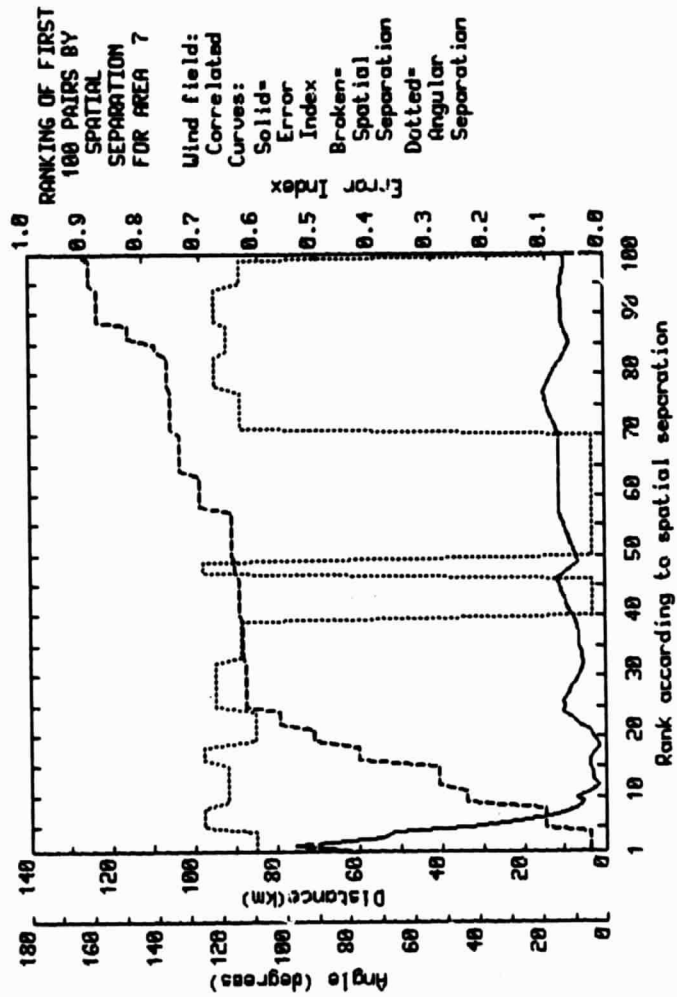


FIGURE 2

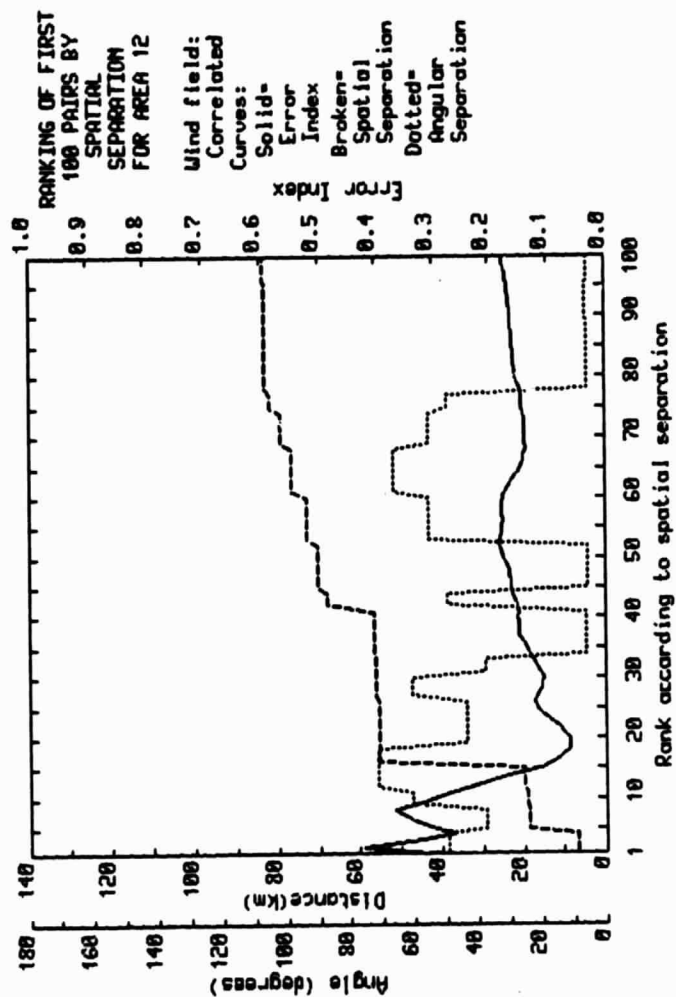
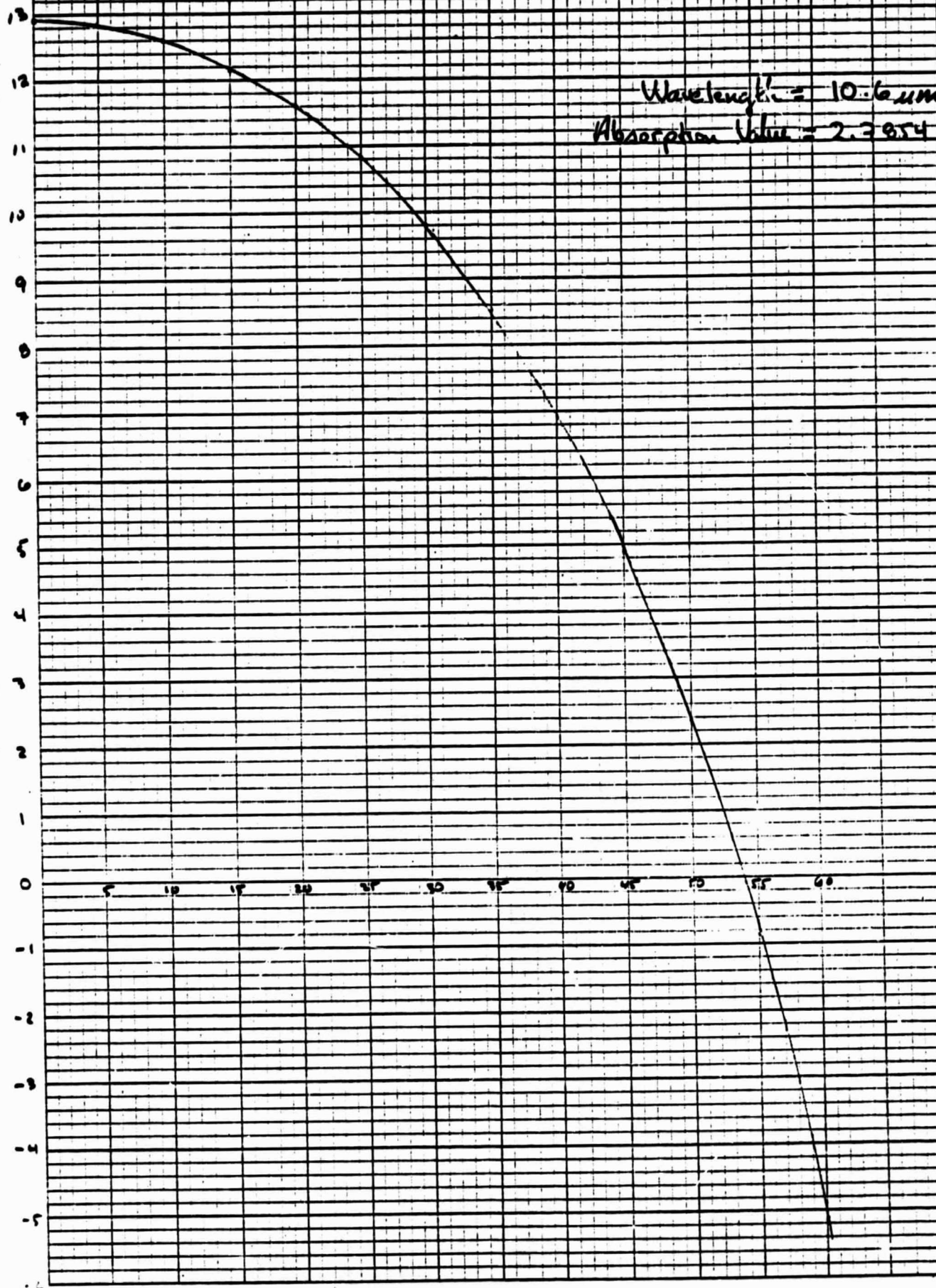


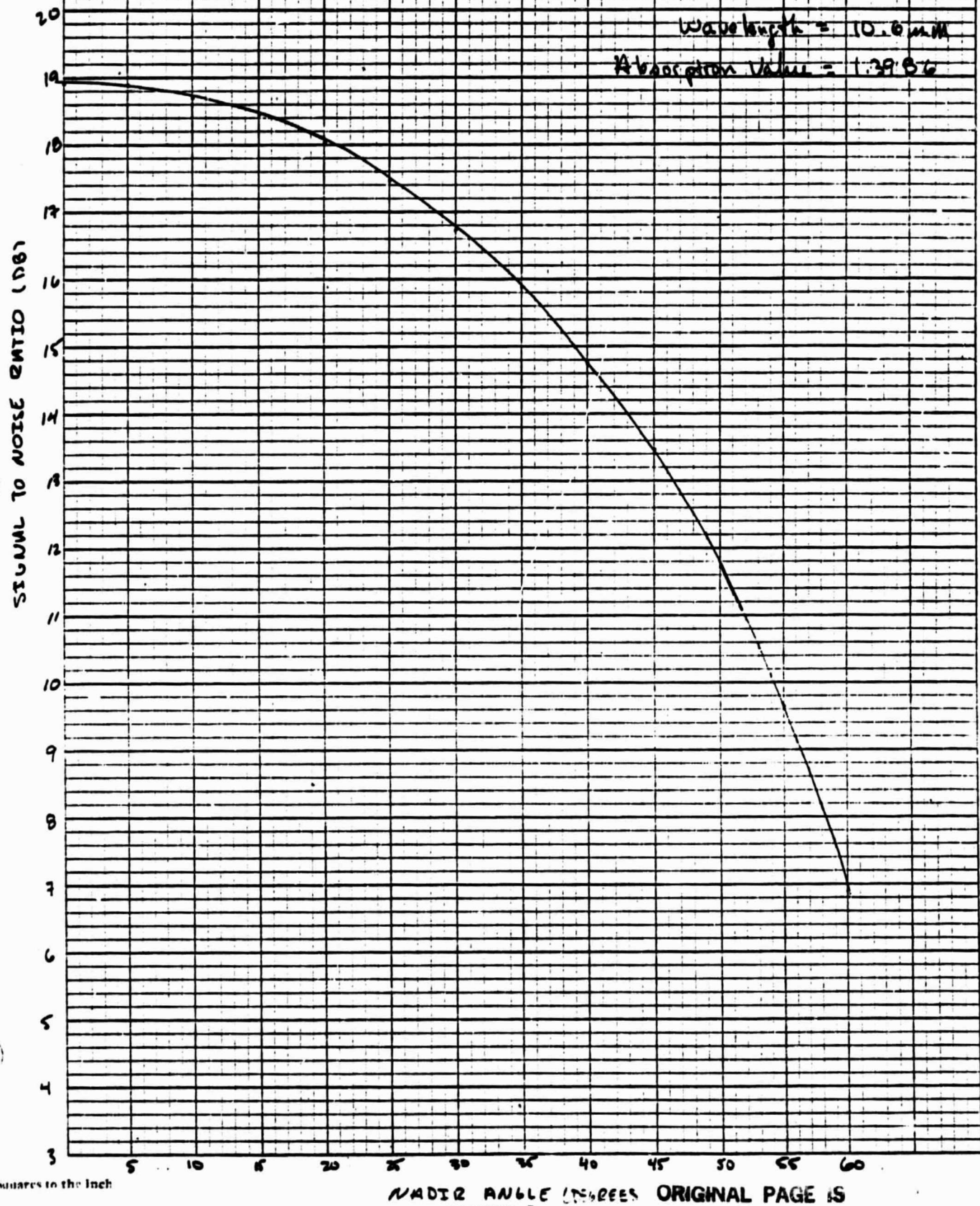
FIGURE 3

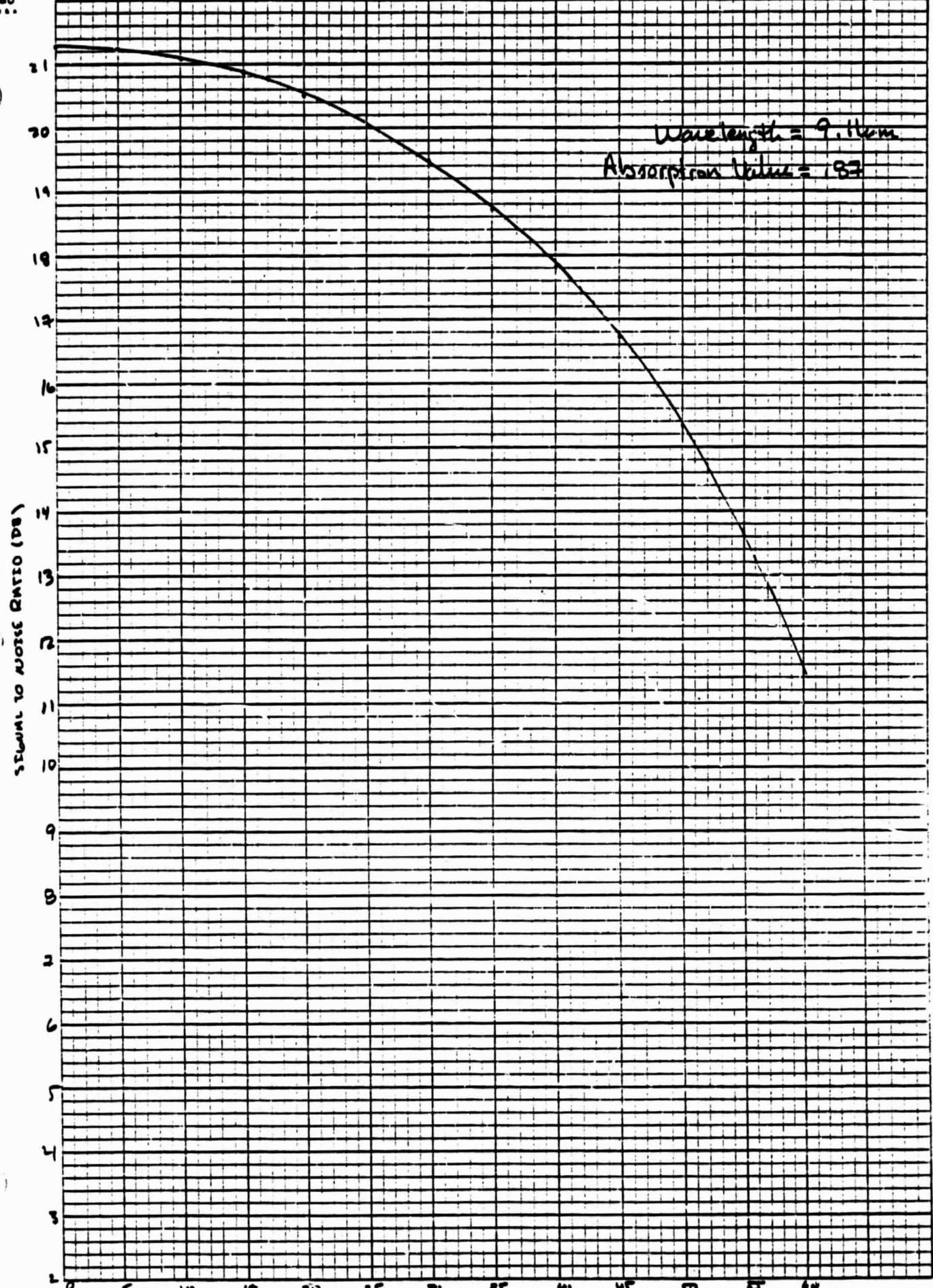
SIGNAL TO NOISE RATIO (DB)



NADIR ANGLE (DEGREES)
FIGURE 4

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10 Squares to the Inch

AZIMUTH ANGLE (DEGREES)

FIGURE 6

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RELATIVE TO NORMAL (DB)

Wavelength = 9.11 cm
Absorption Value = .0812

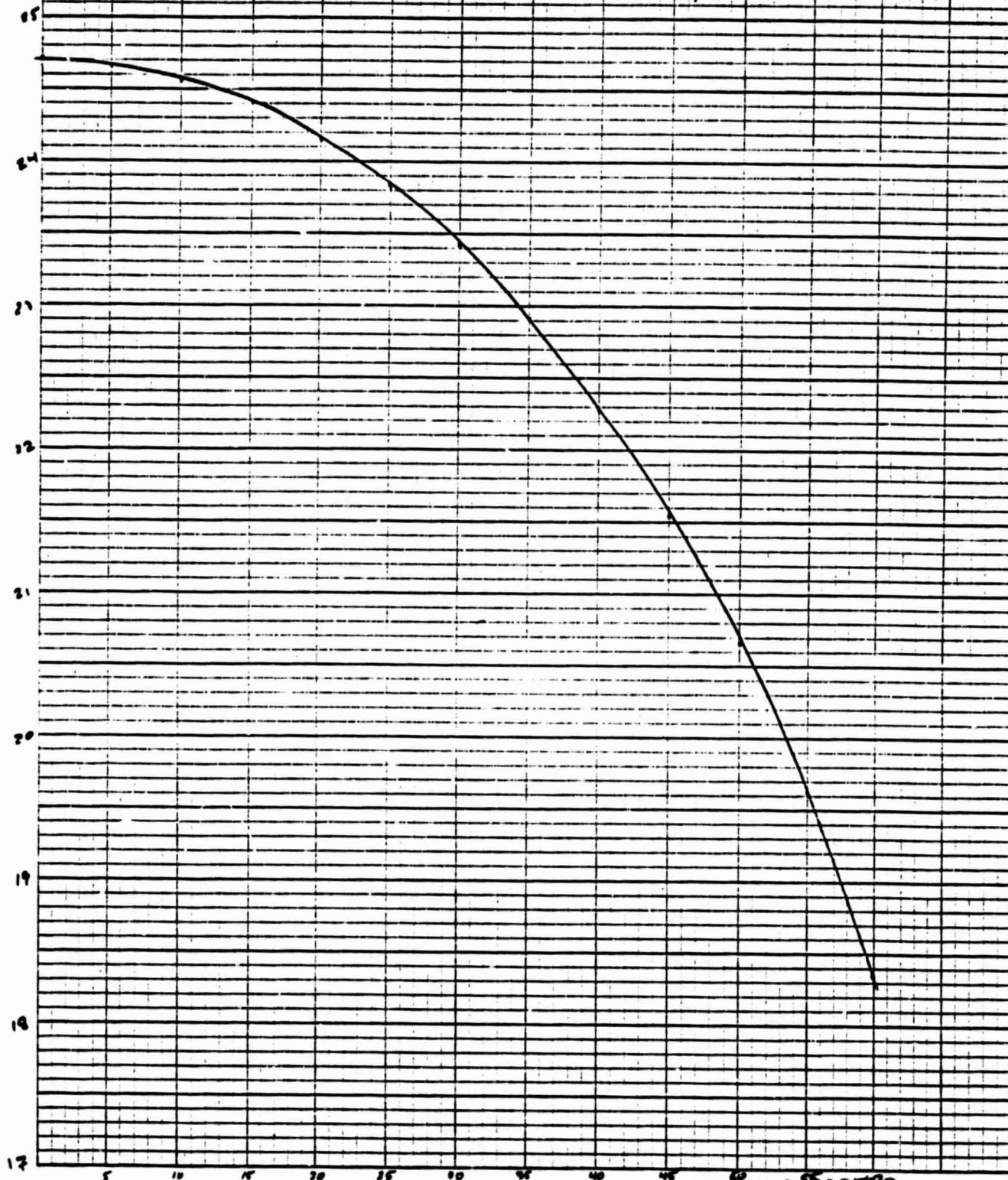


FIGURE 7

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SHUTTLE BASED DOPPLER LIDAR SHOT DISTRIBUTION

□=forward shot
+=aft shot

PRF =0.2
Scan Period=180
Mod. Amp. =0.00

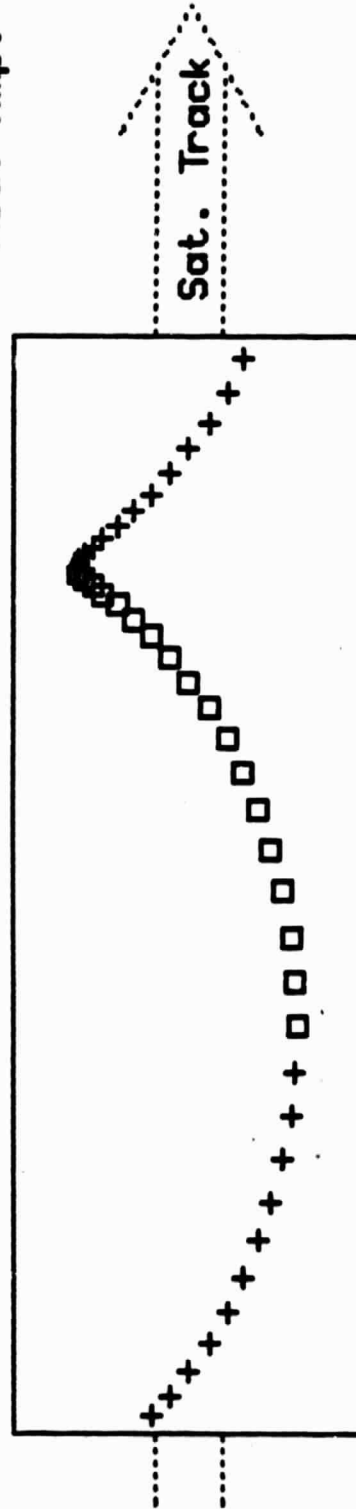


FIGURE 8

SHUTTLE BASED
DOPPLER
LIDAR WINDS

— mean input
wind

— computed wind

300 x 300 km

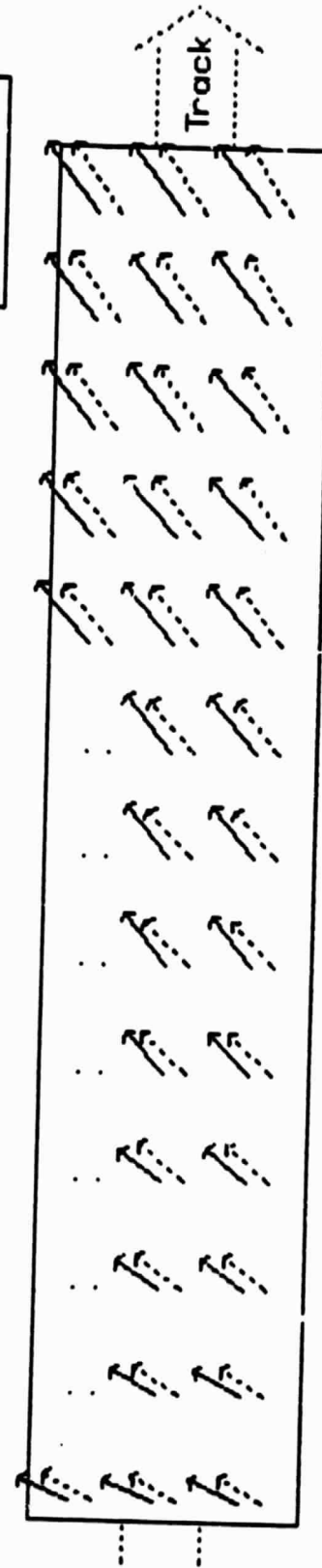
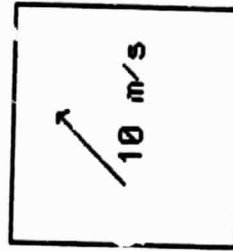


FIGURE 9

SHUTTLE BASED DOPPLER LIDAR WINDS

↗ - mean input
wind

↘ - computed wind

300 x 300 km

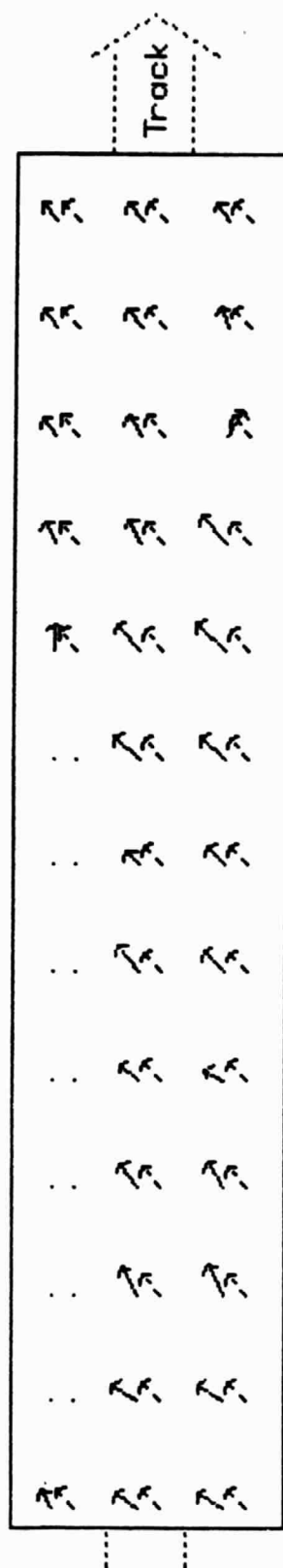
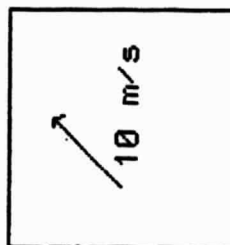


FIGURE 10